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A CRETACEOUS AND LOWER TERTIARY SECTION IN SOUTH CENTRAL MONTANA.

(Plate XXIX.)

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(*Read April 3, 1902.*)

This paper is intended only as a preliminary report of an interesting geological section—an account of what has been done and a suggestion of what is yet to be accomplished. The points of interest are: (1) The completeness of the Upper Cretaceous which overlies the older beds, probably Jurassic and Lower Cretaceous, and underlies the Fort Union, which here contains mammalian remains, correlating it with the Torrejon of New Mexico; (2) the excellent exposures of the strata, giving a good opportunity for study; and (3) the occurrence of interesting fossils, especially vertebrates, in several different horizons.

The region here referred to lies east of the Crazy Mountains and south of the Big Snowies, in the basin of the Musselshell River, in Sweetgrass County. It extends from south of the Musselshell River southward twelve or fifteen miles, and eastward from a line passing southward from Harlowton on the Musselshell about the same distance. This is part of the south limb of a broad anticline, the general trend of which is south of east. This anticline is dissected longitudinally by the Musselshell. The lowest strata exposed are upheaved into a dome-shaped uplift southeast of Harlowton and four or five miles south of the river, where strata which are apparently of Jurassic age are exposed.

This region is on the western border of the elevated plains country, and occupies a position intermediate between the plains and

the foothills. The strata are, as a rule, not horizontal, but have been affected by the disturbances which have elevated the mountains farther to the west or north. In restricted localities the beds are horizontal and in others nearly vertical, and there are all intermediate grades. The average dip is probably not more than fifteen or twenty degrees.

The relief beautifully expresses the geological character. Through the whole section there are alternations of sandstones and shales and all grades between the two. Sometimes, as in the Fort Benton and Fort Pierre, the shales predominate and attain a considerable thickness. Again, as in the Dakota (?), Niobrara, Fox Hills, etc., sandstones predominate—at least there is enough indurated sandstone to retard erosion and to produce prominent ridges which can be followed for long distances—fifty miles or more. In all the formations there is considerable sandstone, and in all there is much shale; but I have seen but very little limestone in the whole section, though it sometimes occurs in concretions or in thin layers.

It does not appear that during the whole period of deposition the sea ever attained any great depth. Probably it was deepest at times during the Benton epoch, yet even here the great amount of sand in the shales indicates near-shore deposition. The erosion features will be given in the descriptions of the different formations.

So far as I am aware this particular region has been described only by the writer (see *Science*, January 3, 1902, p. 31, and February 14, 1902, p. 272). A little to the west is the area mapped in the Little Belt Folio (No. 56) of the U. S. Geol. Survey, and some work was done to the eastward on Swimming Woman and Careless Creeks by W. Lindgren and George H. Eldrege, in connection with the Northern Transcontinental Survey.[1]

Of course there is no single section where all the features here described can be seen, and the depressions or ridges into which the different strata weather have frequently to be followed for a few miles to obtain good exposures. Fortunately this is easily done.

The Lake Basin, to which reference will frequently be made, is a large, depressed area nearly fifty miles long east and west and twenty-five miles north and south in the widest portion. The former represents the greatest east and west extension. The eastern portion extends northeastward. This portion I have not ex-

[1] *Tenth Census of the United States*, Vol. XV, p. 243.

plored. The basin has no outward drainage, but has several small lakes without outlets, into which small streams empty, when there is an excess of precipitation. The basin is bounded on the south by the high rocky bluffs of the Fox Hills, and on the north, at least in the western portion, by the hard sandstones of the Niobrara and the Dakota (?). The name Lake Basin seems doubly appropriate, for it not only contains lakes, but it resembles the bed of some ancient body of water with bays and inlets, and with capes, promonotories and peninsulas extending into it from the southward. The scene is spread out like a great panorama; the southern hills and northern ridges become hazy in the distance and the farther border seems a dim ridge on the eastern horizon. At the foot of the Fox Hills bluffs are the Fort Pierre shales and still farther away the Fish Creek beds.

As the principal object of this paper is to show something of the characters of the uppermost Cretaceous and Lower Tertiary formations in this locality, and to give a little light tending toward the clearing up of the problem concerning the boundary between the Mesozoic and the Cenozoic ages in the Rocky Mountains, I will give only a brief sketch of the formations lower than the Niobrara.

Jurassic, etc.

The supposed Jurassic is exposed in a dome-shaped uplift, so that the strike of the outcrop is nearly a circle. The beds are sandstones and sandy clays. The latter are largely red in color. This is apparently due to the combustion of coal. There are bones of large *Dinosaurs* and of some smaller reptiles, but they have not been studied. It is possible that this stratum with the sandstones above may belong to the Lower Cretaceous. There are many hundreds of feet of hard sandstones and shales between the fossil-bearing horizon and the Fort Benton. The upper portion probably belongs to the Dakota formation.

The Fort Benton Formation.

These beds and their contained fossils are much like the corresponding ones in other regions. They are principally dark shales with bands of sandstone in the lower portion, and in one place I found a half dozen specimens of *Prionocyclus* Meek in brown concretions in the shales. Higher were *Ammonites*, *Scaphites*, *Inoce-*

rami, small *Baculites* and other *Mollusca*, all of Benton types. These shales weather into ravines between the sandstones of the Dakota below and the Niobrara above.

Niobrara.

In the Niobrara gray sandstones predominate, though there are beds of shale. This differs from the usual character of this formation in most other regions where it has been observed. It has usually been described as being composed principally of limestone and marl, though sometimes containing considerable sand. The sandstones here are very much like some of those of the Laramie, and near the middle portion are seams of coal. In two or three places I looked in vain for any well-preserved plant remains in the carbonaceous shales and in the sandstones above and below the coal, and followed ravines cutting through the prominent sandstone ridges without finding any good fossils. However, about twenty miles to the southeastward a few plant impressions were found—the best of which was apparently a *Sequoia*—in beds which I take to be Niobrara. Undoubtedly, by careful, continued search, a fair collection could be obtained.

In one place, where Mud Creek cuts through the formation, the beds approach near to a vertical position. I should not estimate the thickness to be less than 700 or 800 feet here. It may be more. The sandstones form a prominent ridge where they are much inclined. These ridges are sometimes wooded, though the trees are usually not very large or numerous.

Fish Creek Beds.

Above the Niobrara are beds which I believe to belong to the Belly River formation, but until they are certainly correlated with the latter I give them the above name.

They are best exposed between Fish Creek and Mud Creek, only a few miles from where the latter empties into the Musselshell River. Here they are nearly horizontal, while the underlying Niobrara dips at a considerable angle to the southward. Farther to the east and west I did not notice any unconformity between the two formations. In the above-mentioned locality, where they are horizontal, they weather into "bad land" forms. The material is principally rather soft sandy clay, with hard, almost black concre-

tions and hard sandstone layers. In the latter there are, in some places, plant impressions. The softer layers contain fossil wood, bivalve mollusks, turtles and bones of *Dinosaurs* of the genus *Claosaurus*. The bones are generally petrified and occur also in the dark concretions which also contain plant remains. Though they are, as a rule, excellently preserved, yet sometimes there is what seems to be a good portion of a Dinosaur broken into myriads of little fragments. The beds are probably either fresh or brackish water.

This formation was observed in several places in this region, and in all there were bone fragments; but we found no other equally good exposures. About twenty-five miles to the southeast, in the Lake Basin north of Columbus, the formation lying immediately below the Fort Pierre in one place has a considerable thickness of sandstone containing petrified logs, but only one or two small fragments of bone were found. Some of the plants of this formation are related to *Sequoia*. The bivalve shells were so fragile as to crumble with the soft matrix in which they were imbedded.

Lying over these beds is a series of shales and hard laminated sandstones. Some fossil leaves were seen in the latter. A series of dark shales, perhaps thirty feet thick, was carefully examined. The shales were full of carbonaceous plant fragments, and some fairly good leaves were found in the thin interbedded layers of sand or sandy concretions. I do not know whether these beds should be put in this series or in the Fort Pierre. I think it better to consider them, until they are more thoroughly explored, as belonging to the Fish Creek series.

Fort Pierre.

Above the beds just described are the Fort Pierre shales. This represents a well-distinguished horizon, so well marked by lithological characters and by characteristic fossils that its position is beyond doubt. The description of the Pierre in Colorado, Wyoming, etc., would answer almost equally well for the formation here. Dark, soft shales predominate. There are occasional thin bands of sand and many brownish concretions which break into angular fragments. These sometimes contain marine fossils and sometimes a network of calcite seams. The best preserved invertebrate fossils are in these concretions. The shells are those of *Ammonites*, *Baculites*, *Scaphites*, *Nautili*, and small *Gasteropods* and *Cephalopods*.

Some hard limestone concretions are crowded with these small molluscs.

What distinguishes the Pierre here from that in other places is the presence of many vertebrate fossils. Several *Mosasaurs* have been found. In the summer of 1900, Mr. Albert Silberling and I found portions of two individuals, including a skull. In the summer of 1901, the Princeton Expedition in charge of Dr. M. S. Farr procured a nearly complete skeleton except the skull.

But the most interesting fossil remains are those of the *Dinosaurs*. They have been found to be more numerous here than the *Mosasaurs*. The greater number of them belong to the genus *Claosaurus* and apparently to described species. Two portions of skeletons belong to quadrupedal type, probably to the *Ceratopsidæ*. A *Claosaurus* skull and the greater part of the skeleton was obtained for the Princeton Museum last summer (1901). The digging was easy, but the removal of the bones was slow and tedious, as they had to be hardened. Nodules had formed around some of them, but many were in clear shale. The skeleton was just above a layer of yellowish, partly consolidated sandstone two or three inches in thickness. There were some thin layers or lenses in the shale, in which the remains were imbedded. There was also a minute seam of coal not thicker than cardboard. Cones or ends of twigs of what appeared to be *Sequoia*, Ammonites, Scaphites, Baculites and other molluscs, and shark's teeth were found in the matrix while removing the skeleton. Only the teeth and a few of the shells could be preserved, as the fossils in the shale disintegrated on exposure to the sun and rain. The deeper into the shale excavation was made, the larger the flakes into which it would break. Quite a number of other portions of skeletons were found during this and the previous year. Often the bones are solid, though lying among the grass roots, where the soil is composed of the disintegrated shales. Sometimes the nodules surrounding the bones are very hard and flinty.

The finding of *Dinosaur* remains in these marine beds was unexpected, but the sea was evidently shallow. In some places there is much gypsum in good-sized crystals, or in minute ones scattered through the shales.

The Pierre beds being soft, have weathered into depressions. They are usually covered, except in restricted portions, with a good growth of grass, but are treeless except for a few small willows or

cottonwoods that occasionally grow along the streams. They make grass-clad rolling prairies, with small ravines cutting into the soft shales.

The transition beds between the Fort Pierre and Fox Hills are usually obscured by the material washed down from the bluffs of the latter; but on the ranch of Mr. B. Forsythe, near the head of a branch of Big Coulee Creek, they can be nicely seen. The shales gradually become more sandy, and contain bands of sandstone until the latter predominates and the shales become shaly sandstones or sandy clays. In them I found no trace of fossils.

Fox Hills.

In this formation the hard sandstones form a prominent ridge adjoining the depression made by the Pierre. It is the next prominent ridge above the Niobrara. I have followed its base for about thirty-five or forty miles. In only one place was there any confusion or any difficulty in tracing it, and this was caused by some change in the geological structure obscuring the Pierre shales. The outcrop extends southeast and northwest. It forms the southern rim of the Lake Basin. It furnishes many springs which, uniting their waters, produce little streams that cut through the rocky ridge and flow out upon the Pierre flats. In the Fish Creek region they empty into Fish Creek. In the Lake Basin, if the water does not soak into the ground, they flow into the land-locked lakes. Where the streams form little cañons and ravines through the Fox Hills strata, they are fringed with trees and shrubbery. In little valleys and amphitheatres there are often springs surrounded by groves, which are very picturesque, and in the heat of summer these places form a delightful retreat from the almost treeless wastes around. The trees, which are principally evergreens, cottonwoods, poplars and willows, follow the streams a little way toward the Pierre flats and then disappear.

Though these beds usually appear to be sandstone ridges, yet in places where conditions of weathering are favorable they are seen to contain much sandy clay, and in places for a short distance resemble "bad land" forms.

Fossil leaves and reptilian bone fragments were found in considerable abundance. Dr. Farr brought back some of the fossil leaves, but they have not yet been determined. Most of the bones are too fragmentary to be of much use. Some teeth were recognized as

belonging to *Claosaurus*. The only fossil plant we were able to recognize in the field was a species of *Salisburia*.

Though this is probably still below the Laramie—at least there are thousands of feet of what is apparently Laramie above it—yet this is the highest level in which we found *Dinosaur* remains in this region. This is interesting, as in other regions the *Claosaurs*, with one exception, have come from beds which have been supposed to be above the Fox Hills.

It is not certain just where the Fox Hills ends and the Laramie begins. It is possible that these bones, or at least some of them, are in the lowest Laramie; but as the two formations represent differences in conditions of depositions rather than difference in age, as distinguished by change or progression of the fauna or flora, it is not so essential, except as bearing on the more interesting question of the extinction of a very remarkable class of animals and the occupation of their territory by a class that had for millions of years held a subordinate position.

Above the Pierre, in the Fish Creek region, are alternations of dark shales and gray sandstones. In places the sandstone is warped, twisted or made up of imperfectly concentric layers. Above these are brownish laminated and greenish or brownish unlaminated sandstones and sandy clays. Provisionally, I place the base of the Laramie above these latter beds. They contain fossil leaves and bone fragments.

Laramie.

The lowest beds, which are here taken to be Laramie, are a series of alternating various-colored shales and gray unlaminated sandstones. There are several hundreds of feet of these and no fossils were found in them. There are in some layers brownish concretions, some of which are large and composed of sandstone. These beds form a depression, but not so low as that of the Pierre shales.

Over these lies about an equal thickness of similar sandstones and gray shales. The former are harder and form a bench or ridge. There are several thin seams of coaly matter and the shales hold impressions of ferns and other delicate plants different from what we observed elsewhere.

Near or at the top of this series there are at least two layers containing non-marine fossils. In one of the fossils are principally *Gasteropods* and in the other bivalves—probably *Unio*. It

is said that this layer extends for twenty miles up Fish Creek, but I have not tried to trace it, so do not know whether it is continuous or not. It is also said that these fossils gave the Mussel-shell River its name. Here we may be quite sure that we are in the Laramie, for fresh or brackish water conditions prevail, but it probably extends between 1000 and 2000 feet below.

Still higher are shales forming a flat or depression, above which are conical hills or hog-backs—the remains of dissected ridges cut through by ravines and by streams which are fed by springs in the Fort Union sandstone above. These hills or ridges are capped with brownish, compact, laminated sandstone. No fossils were seen except fragments of wood in the shale.

Above these sandstones dark shales again predominate. I cannot tell, at least without more careful study and observation, where the Laramie terminates and the Fort Union begins. In fact, it looks as if there were in this section almost continuous deposition from the Jurassic up. We found here no traces of the volcanic material of the Livingston formation, which only thirty or forty miles to the southwest is so well developed. It appears that here deposition went on quietly and uninterruptedly. There is little doubt that part of the strata were deposited synchronously with those of the Livingston. Here, so far as we have discovered, as in other places, Nature has left no waymarks and laid down no boundary line to distinguish between the great "Age of Reptiles" and the "Age of Mammals." There appears to be no sign of the disturbance that is supposed to have closed the Mesozoic and brought in a new order of things; yet only a few miles away there was a region of upheaval and of intense volcanic activity. The strata in the section under consideration have been disturbed, but the Tertiary beds are also involved in the upheaval. Perhaps microscopic or chemical examination may reveal the presence of fine volcanic material here.

Mr. W. Lindgren made three different measurements of the Laramie to the eastward of this region (see *Tenth Census of the United States*, Vol. XV, p. 744). In none of these does he make the thickness of the Lower Laramie to be less than 7000 feet. I do not think that this, as C. A. White[1] thinks probable, includes the Belly River, or anything lower than Fort Pierre. Lindgren's Upper Laramie, or Bull Mountain series, is probably Tertiary—apparently

[1] "Correlation Paper, Cretaceous," *Bull. 84, U. S. Geol. Survey*, p. 174.

Fort Union. What is supposed to be Laramie in the present section is very thick, probably approximating that of Lindgren's measurements. But here, as everywhere else, the boundaries of the Laramie are uncertain. Here, however, we have it confined between certain limits. We have below a characteristic Fort Pierre fauna and above a characteristic Fort Union flora. Just how much of that which intervenes is Laramie is not known. I have no doubt that here deposition was going on at the same time as that of not only the Livingston, but also of the Arapahoe and Denver beds. Whether these beds will ultimately be assigned to the Upper Laramie, or included in a separate formation, depends upon the results of future careful investigation.

Tertiary.

Fort Union.

The dark shales just mentioned continue upward, changing little in character; but brown concretions become numerous, then layers containing shells of bivalve Mollusca, then occasional layers of sandstone, and above these, often capping the bluffs, heavy gray sandstones, usually hard, sometimes laminated and sometimes massive. Above this I cannot speak definitely, but think that the Fort Union continues much higher. The strata from the top of the bluffs south of Fish Creek, which make a bench sloping toward Sweetgrass Creek in the direction of Melville, perhaps belong to higher members of this formation. The strata are not always continuous for great distances, but vary locally; yet a general description can be given that will apply fairly well to the beds examined. There are dark gray shales that in many places weather to thin, flaky particles on the surface. The wind blows away this light material and leaves bare depressions without vegetation. The sandstones are usually hard, sometimes massive or imperfectly bedded, and in some places break into great blocks, which tumble down the steep sides of the bluffs.

In the Fish Creek region these heavy sandstones, which lie above the soft shales, form a long line of rugged bluffs extending along the south side of the creek from the neighborhood of Porcupine Butte eastward for twenty-five or thirty miles; then it extends southeastward, probably forming the divide between the Sweetgrass on the southwest and the southern branches of Fish Creek and Big

Coulee Creek; but I have not examined all of this territory. I examined hastily the beds on Sweetgrass Creek east and a little north of Big Timber, where I made a collection of fossil leaves. The remains of a turtle were also found in the shale.

The portion of the Fort Union described in this paper apparently represents the upper portion of the Crazy Mountain section, as given by Weed in the *American Geologist* of October, 1896.

Fossil plants, *Unios* and *Gasteropods*, are abundant and may occur in any part of the beds favorable for their preservation. Last summer (1901) determinable Mammalian remains were found. As is well known, the exact position of these beds has been a matter of some doubt and difference of opinion. They have usually been assigned to the Tertiary, though they have been placed as low as the Cretaceous and as high as the Miocene.

The bones and teeth of *Mammals* which were found[1] are not numerous, but are sufficient to show that the beds are of nearly the same age as the Torrejon of New Mexico. They are:

Mioclænus acolytus (Cope).
Anisonchus very near to *A. sectorius* Cope.
Euprotogonia puercensis (Cope).
Pantolambda cavirictis (?).
Pantolambda (?), a small species.
Some others are doubtful.

I felt very certain that these beds were Fort Union, but to settle the matter forever and leave no room for a shadow of doubt, a box of fossil leaves was sent to Mr. F. H. Knowlton, of the United States Geological Survey. Mr. Knowlton examined them at once and sent me a list, which I quote:

Pterospermites cupanioides (Newb.) Knowlton.
Populus speciosa Ward.
Populus amblyrhyncha Ward.
Ulmus orbicularis ? Ward.
Vitis xantholithensis Ward.
Populus daphnozenoides Ward.
Populus arctica ? Heer.
Platanus aceroides Göpp.
Celastrus sp.
Grewia crenata (Ung.) Heer.

[1] *Science*, February 14, 1902, pp. 272, 273.

Viburnum asperum ? Newb.
Populus cuneata Newb.
Populus sp.
Platanus nobilis Newb.
Platanus basilobata Ward.
Viburnum sp.
Paliurus sp.
Grewiopsis viburnifolia Ward.
Populus ? n. sp.

Mr. Knowlton says: "The species are all Fort Union beyond a doubt."

Of a few shells which I enclosed, he writes: "The shells I showed to Mr. Stanton, and he says that the two large ones are *Unio Couesi* White; and the other pretty near to *Unio Endlichi* White."

The *Mammals* were found in the shale. The collection of fossil leaves was made in the sandstone a little higher up, though there are concretions and layers of sandstone that contain leaves in the same beds as the Mammalian remains. A portion of the collection was obtained on Sweetgrass Creek north of east of Big Timber, in the locality mentioned above.

General Observations.

The problem of greatest interest connected with the study of this section is that relating to the transition from Mesozoic to Cenozoic times. Of course, if deposition had been continuous, or nearly so, and there were no great faunal or floral migrations, there could be no distinct boundary between the two. There is a great difference between the Cretaceous as a whole and the Tertiary as a whole, but where are we to draw the line? If there was a time of widespread or general upheaval throughout the western portion of the continent, or of the Rocky Mountain region, this might form a convenient division. Upheavals and great volcanic activity certainly occurred in restricted localities, but we cannot at present prove that such were general or that they did not occur in different places and at different times. If we could point to any time when the *Dinosaurs* ceased to be and the higher orders of *Mammals* took their places, then the matter would be easy; but heretofore most of the Cretaceous *Dinosaurs*, in fact nearly all of them, have been

supposed to come from the uppermost portion of the Cretaceous—the Laramie—but the other fossils found in these beds have not been of a character to settle the doubt concerning the horizon. There is no direct proof that the Dinosaurs died out before higher forms of Mammals became numerous. Though they have not yet, so far as I know, been found in the same beds, yet there seems good reason for believing that Dinosaurs were contemporaneous with Puerco Mammals. Were it not for the "Ceratops fauna" and the discovery of a few specimens in the eastern United States and one in Kansas, we should say that the Dinosaurs died out at the end of the Jurassic. It would seem that if anything had a chance of being preserved it would be the large, solid bones of these animals; yet there are miles of thickness of strata and thousands of square miles of exposure of Lower Cretaceous, Dakota and Colorado beds, and nothing, I believe, has been found to tell that these animals still lived in this great Cordilleran region, except the type of *Claosaurus agilis* from the Niobrara of Nebraska. This rock must represent many millions of years in which Dinosaurs lived, flourished and progressed. To our view they disappear in their glory, and after ages appear again in glory but transformed; again they suddenly disappear and we see them no more. The morning, midday and evening of their splendor is lost to us. Until the discovery of the beds described in this paper almost nothing was known of them in the Montana formation, at least the beds from which they had been collected had not been considered as belonging to that age. The point the writer wishes to make is this: It is extremely unsafe to say when and where these strange reptiles breathed their last, for the presence of fossils is certain evidence of the existence of life, but the lack of them is no evidence of its absence. Dinosaurs may have continued long in the Eocene, but conditions in the places where so many Mammalian remains have been found may not have been favorable for them.

I think we can hardly account for the general absence of Dinosaur remains in the Kootenai and Upper Cretaceous, below the Laramie, by the beds being in part marine. Much of the strata is evidently fresh or brackish water. We should hardly expect to find them in the Benton and Fort Pierre shales associated with large marine Mollusca, yet as previously stated *we do find them* in the latter. This proves that these animals lived near the sea or where they could float into it. Why don't we get them then in the many

thousands of feet of sandstone which, if marine, must be near-shore deposits? It is true that any day we may hear of their being found in some of these strata, and we may also hear of their being found in Eocene strata, if they have not been found there already.

As shown by this paper, the presence of *Claosauridæ*, and probably of *Ceratopsidæ*, is far from showing that the beds in which they are found are as late as Laramie—I mean as the Laramie as it is understood. It is true that the Fort Pierre, and in some places the Fox Hills with it, represents an incursion of the sea, and that conditions of life were not greatly different during the time of the deposition of the Belly River beds from what they were in the Laramie.

At present the fossil plants, together with orographic movements and their results when they occur, are the only things we can use to distinguish these doubtful formations as the Laramie, Livingston, Denver, etc. The plants, on account of mixtures of the flora of different horizons in collecting, have not been available for use until the material has been carefully separated. As Mr. Knowlton has been doing this work, his forthcoming monograph on the Flora of the Laramie and Allied Formations will be looked for with interest.

There is not much doubt that the Livingston in Montana represents the upper portion of what has been called the Laramie in the plains region farther to the east. Both have Laramie strata below; both are overlaid by Fort Union beds. In Colorado it seems that the Arapahoe, and probably the Denver, or the greater part of it, sustains the same relation to Laramie. Mr. Knowlton says: "From these considerations it appears beyond question that the flora of the Livingston formation finds its nearest relationship with the Denver beds of Colorado."[1] If the Livingston and Denver are of the same age, as has for some time been suspected, then the Denver must be older than the Fort Union, and therefore older than the Torrejon. With its apparently Cretaceous Vertebrate fauna, we are not warranted at present in placing the Denver much higher than the Livingston. It may be in part contemporaneous with the Fort Union.

The Puerco should be nearly of the same age, as it lies between Laramie and Fort Union (Torrejon) strata.

Below is given a table which is intended to show the probable

[1] *Bull. 105, U. S. Geol. Survey*, p. 63.

relations in time of the formations under consideration concerning which there is doubt:

Table Showing Probable Relations of the Laramie and Overlying Beds in Different Regions.

	Cretaceous.			*Tertiary.*
In Wyoming	Laramie of King			
Plains of Montana	Laramie			Fort Union
Crazy Mts., Montana	Laramie		Livingston	Fort Union
Denver Basin	Laramie	Arapahoe	Denver	
Puerco River, N. Mex.	Laramie		Puerco	Torrejon

The names given are the ones by which the different divisions have been called. There does not seem to be much doubt that the Livingston, Denver, Puerco, etc., are contemporaneous with what in other places has been assigned to the upper portion of the Laramie. Whether all will be included in the Laramie later will depend on the results of further careful investigation. I have indicated the doubtful division between the Cretaceous and Tertiary by a dotted vertical line passing between the Livingston and Fort Union and between the Puerco and Torrejon, or approximately so, not claiming that the time division line between the two sets of strata would fall exactly in the same place. The horizontal parallel lines are intended to represent contemporaneity of deposition. Deposition in the Denver Basin was not continuous and the blank spaces indicate non-deposition. The broken or dotted lines indicate probable continuity.

Remarks on the Fossil Mammals.

The mammals are represented by about a half dozen species. Five of these are represented by teeth. Almost any one of these

taken alone would strongly incline one to the belief that the formation containing them is contemporaneous with the Torrejon of New Mexico. This is made still stronger by nearly every specimen. There are a radius and ulna which are different from any found in New Mexico, so that they cannot be assigned to any genus with certainty, and there is a premolar much like that of Pantolambda, but indicating an animal much smaller than any species of that genus, to which, however, I refer it with doubt. The other four are cogeneric if not cospecific with Torrejon forms.

Mioclænus acolytus (Cope). (Plate XXIX, Figs. 9 and 10.)

This is represented by a small portion of a mandible with a molar tooth which is almost unworn. The anterior cusps are connate at base and much higher than the posterior ones.

Anisonchus Cope. (Plate XXIX, Figs. 3–5.)

This is also represented by a portion of a mandible. There are two teeth, a fourth premolar and a first molar. They are of nearly equal length. In size and character the teeth are nearly like *A. sectorius* Cope. It may, however, be another species.

Euprotogonia puercensis (Cope). (Plate XXIX, Figs. 6–8.)

Represented by a third premolar and a second molar of the right side and a third molar of the left. The molars differ somewhat from the type. Matthew has carefully studied the many specimens in the American Museum collection and finds a wide range of variation in the teeth, but no constant characters that will serve to separate the various forms which Cope has named. Of the many specimens no two appear to be exactly alike. I have compared the present specimens with those in the above collection and find that they do not differ so much from some of the American Museum specimens, as the latter vary among themselves. What comes nearest to being a distinguishing character is the smallness of the hypocone as compared with the protocone, but this is at least *nearly* paralleled by some of the above-named specimens.

Pantolambda (?) (Plate XXIX, Figs. 1, 2, 14.)

There are the greater portions of a radius and ulna, and two phalanges which are different from anything described from the

Torrejon. They more resemble in some respects the corresponding bones of *Coryphodon*.

The ulna is much larger than the radius, is broad antero-posteriorly but narrow transversely. The upper portion of the olecranon is broken off, but a cross section above the glenoid cavity is triangular with the anterior edge thin. The sigmoid cavity is convex transversely. The outer portion is much less convex longitudinally than the inner; it extends lower and its upper portion makes an oblique emargination on the outer side of the olecranon. There are two fairly large surfaces for articulation with the radius. The upper outer surface of the bone has a quite deep longitudinal furrow which dies out near the middle of the shaft. The inner surface is longitudinally concave from the olecranon to the enlargement near the distal end of the bone, where there is considerable swelling and roughening. The distal articular surface is elliptical, slightly concave palmo-dorsally and convex transversely. This surface is very slightly oblique to the long axis of the bone.

The radius is subcylindrical above. The head is partly broken, but the surface for articulation with the humerus is shallow and appears to have been nearly circular. There is a longitudinal roughening on the ulnar side, to correspond with similar rugosities on the radial side of the ulna. Below these is a rugosity on the antero-inner side of the radius and on the opposite side. The bone has the appearance of being twisted on itself. The form of the bone suggests freedom of motion of the limb other than a fore-and-aft movement.

A proximal and medial phalanx apparently do not differ greatly from those figured in Osborn's paper on "Evolution of the Amblypoda."[1]

	M.
Length of ulna from upper portion of glenoid cavity	.1970
Antero-posterior diameter at middle of shaft	.0310
Transverse diameter at middle of shaft	.0143
Transverse diameter of shaft of ulna at middle	.0195

Pantolambda cavirictis Cope (?).

Fragments of upper jaw, with teeth from which enamel has been removed. The size is nearly the same as the corresponding teeth

[1] *Bull. Amer. Mus. Nat. Hist.*, Vol. X, p. 187.

of *P. cavirictis*, and there is nothing to distinguish it from that species.

Pantolambda (?) sp. (Plate XXIX, Figs. 11–13.)

An upper premolar, much smaller than P^4 of *P. bathmodon* or *P. cavirictis*, but it is possible that it may be a P^2 of nearly as large a form. It is very doubtful, however, whether it belongs to *Pantolambda* at all. The protocone is more conical, the outer slope on the median line of the tooth is steeper and the inner less so. The outer surface near the base of the crown is more concave.

A canine found with the above is not like that of the known species of *Pantolambda*, but can hardly be distinguished from that of modern Carnivores. It probably belongs to some Creodont.

PRINCETON UNIVERSITY, May 24, 1902.

EXPLANATION OF PLATE XXIX.

FIGS. 1 and 2. Ulna and radius possibly belonging to some species of *Pantolambda*. ⅔ natural size.

FIGS. 3–5. *Anisonchus sectorius* (?)
Last lower premolar and first lower molar with portion of mandible. Outer and inner view of mandible and upper view of teeth. × 2.

FIGS. 6–8. *Euprotogonia puercensis*.
6. Right upper second molar. × 2.
7. Left upper third molar. × 2.
8. Right third upper premolar. × 2.

FIGS. 9, 10. *Mioclænus acolytus*.
A lower molar with portion of a mandible. × 2.

FIGS. 11–15. *Pantolambda* (?). Upper premolar. × 2.
13. Canine tooth found with 11.
14. Phalanx found near 1 and 2. × ⅔.
15. Scale of *Lepidosteus* found with mammals. × 2.